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ABSTRACT

Recent research in West Virginia and California has linked school size to both effectiveness and equity, finding that as school size increased, the mean achievement costs for schools with less-advantaged students became more burdensome. An effort was undertaken to replicate this research in four states offering a variety of school settings and conditions. This report describes analysis of 1996-97 data from 1,626 Georgia schools using a multiple regression equation in which the dependent variable was mean achievement test score and independent variables were school size (enrollment per grade level being analyzed), percent of enrollment eligible for free or reduced-cost lunch, and a multiplicative interaction term. Various test scores were analyzed for grades 3, 5, 8, and 11. In 27 of 29 analyses, statistically significant and negative interaction effects were found, such that achievement in schools with less advantaged students decreased as school size increased. Inclusion of two additional independent variables--percent of black students and percent of other minority students--had little effect on regression results. Similar analyses for school district size did not find the size-by-socioeconomic status interaction effect. (Contains 49 references and 33 statistical data tables.) (SV)

SCHOOL SIZE, SOCIOECONOMIC STATUS, AND ACHIEVEMENT: A GEORGIA REPLICATION OF INEQUITY IN EDUCATION

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ABSTRACT

Research on the consequences of variability in school size has a long history. As with so many variables in educational research, empirical investigations of school size effects, over the years, have yielded conflicting results. This has led some researchers to treat school size as a control variable which they are obliged to employ, but which is otherwise uninteresting. Recent research, however, has linked school size to both effectiveness and equity in a new and interesting way: as school size increases, some have found, the mean achievement costs for schools with less-advantaged students become more burdensome. The first reports of this interesting finding and its educational policy implications were based on research using data from California and West Virginia. In an effort to determine if results from these two very different states can be generalized to other settings, we have replicated the research using a Georgia data set. Our findings are the same as those reported for California and West Virginia: as Georgia schools become larger, achievement costs associated with less-advantaged students increase. Finding the same school size effects in three such distinctive states lends credibility to tentative claims that the results are more widely generalizable.

Educational researchers and policymakers have never met an issue they were willing to resolve once and for all. School size is a case in point.

Interest in school size as an explanatory factor waxes and wanes, but never dies. The effect of variability in school size on educational achievement and a variety of related outcomes remains a subject of sometimes intense, sometimes dilatory, disciplined inquiry and debate.

In the following, we replicate recent research which has found interesting and consequential joint or interaction effects involving school size and socioeconomic status. Our replicaton, using a 1996-97 Georgia data set, seeks a tentative answer to one question: as school size increases, are the achievement-based costs for schools with less-advantaged students made worse?

If our analyses yield a provisonal, "yes," they lend credence to the claim that results of prior research on size-by-socioeconomic status interaction effects are of general importance. A "no" would place us in the same position as so many others addressing so many other educational research issues: inconsistent, even conflicting, results from time to time and place to place.

SCHOOL SIZE, A TIMELY ISSUE

Research on the role of school size as a determinant of school performance has a long history and has generated a voluminous literature (see, for example, Barker and Gump, 1964; Guthrie, 1979; McDill, Natriello, and Pallas, 1986; Smith and DeYoung, 1988; Fowler, 1991; Walberg and Walberg, 1994; Khattari, Riley, and Kane, 1997). As with so many commonly invoked explanatory factors in the social and behavioral sciences, research on the effects of school size has, over the years, yielded conflicting findings (Rossmiller, 1987; Caldas, 1993; Lamdin, 1995; Rivkin, Hanushek, and Kain, 1998). As a consequence, school size sometimes has been relegated to the status of an obligatory but uninteresting control variable. Not infrequently, it simply has been ignored (Barr and Dreeben, 1983; Gamoran and Dreeben, 1986; Farkas, 1996; Wyatt, 1996; Hanushek, 1997 and 1998).

Uncertainty as to the import of school size has yielded state-of-the-art school effectiveness research which fails to designate school size a "resource," much less a resource worthy of investigation (Burtless, 1996). A recent school effectiveness review by eleven production function virtuosos, for example, devoted <u>three</u> of its three hundred ninety-six pages to school size (Betts, 1996: 166-

168). Consequences of variability in school size, moreover, were, in passing, judged to be uncertain.

One Size Fits All

One important limitation of most literature covering school size, however, has been failure to examine the interaction of school size with other variables (cf. Howley, 1989; Lee and Smith, 1995; Mok and Flynn, 1996; Riordan, 1997). This deficiency tends to give rise to a one-size-fits-all point of view. Within any school, it may seem, size-related benefits accrue and size-related costs are borne equally by all students (Conant, 1959; Haller, 1992; Haller, Monk, and Tien, 1993; Hemmings, 1996).

Discounting Equity

In an era of cult-of-efficiency institutional restructuring, moreover, questions as to the best size for any school are often expressed in the scientific management terms of organizational effectiveness. In economists terminology, "economies of scale" have frequently been given pride of place (Tholkes and Sederberg, 1990; Haller, Monk, Bear, Griffith, and Moss, 1990; Purdy, 1997). As with much contemporary educational research, equity questions have often been deemed largely irrelevant to the school size discussion (Stevenson, 1996).

Small is Better?

Recently, nevertheless, attention has been drawn by a growing body of empirical research which holds that school size is negatively associated with most measures of educational productivity. This includes measured achievement levels, dropout rates, grade retention rates, and college enrollment rates (see, for example, Walberg and Walberg, 1994; Stevens and Peltier, 1995; Fowler, 1995; Mik and Flynn, 1996).

Size-by-Socioeconomic Status Interaction Effects

In part, renewed interest in smaller schools is due to research concerning the joint or interactive, rather than independent, effects of school size and socioeconomic status (SES). Specifically, interaction effects have been identified which suggest that the well known adverse consequences of socioeconomic disadvantage are tied to school size in substantively important ways.

In brief, as school size increases, the mean measured achievement of schools with less-advantaged students declines. The larger the number of less-advantaged students attending a school, the greater the decline (Freidkin and Necochea, 1988; Howley, 1989 and 1996; Huang and Howley, 1993).

In addition to reviving interest in school size as a variable of importance in educational research, this work has begun to sensitize researchers and policymakers to equity concerns associated with school size. One-size-fits-all is no longer a unanimous judgment. Some researchers and policymakers are now asking best-size-for-whom (Henderson and Raywid, 1994; Devine, 1996)?

FLUKES OR REPRODUCIBLE FINDINGS: A RESEARCH AGENDA

Research on size-by-SES interactions, however, lacks substantial geographic scope. The findings are new, and replications are not numerous (Huang and Howley, 1993). Once again, therefore, as has been the case for so many promising outcomes, there exists the distinct possibility that research done in other locations will yield different, perhaps sharply conflicting results.

Consequently, we have sought to replicate this recent research on size-by-SES interaction effects using data from a variety of settings. One of these is the state of Georgia.

Replication in Georgia

Georgia differs sharply from the two states which occasioned the first reports of size-by-SES interaction effects: enormous, trend-setting, internally heterogeneous, west coast California; and small, rural, internally homogeneous, mid-Atlantic West Virginia (Friedkin and Necochea, 1988; Howley, 1996). Its medium size, unremarkable population composition, deep-southern location, and abundance of urban, suburban, and rural schools make Georgia a distinctive and useful site for a replication.

The credibility of claims to generalizability for size-by-SES interactions will be enhanced if such effects are found in Georgia's schools, as well. On the other hand, if Georgia results contradict findings from other states, or if the interaction effects are simply missing, arguments for generalizability lose credence. We may, once again, be left with interesting findings which prove to be situation specific, or simply ambiguous.

Georgia Data: A Nearly Complete Population

Official documents and proclamations present Georgia as a state with an educational system made up of 1800 public schools (Georgia Department of Education, 1998). The data set we are using, for school year 1996-97, contains complete information on 1626 of them.

The difference in the total number of schools in our data set and the number claimed by the state is due largely to missing test data. Schools limited to grades K-2, for example, are fairly numerous in Georgia. Since test data are available only for grades 3, 5, 8, and 11, such schools are characterized as "missing" because they play no part in our analysis.

The same is sometimes true for specialized alternative programs, particularly those most recently established. The Georgia Department of Education is committed to rapidly increasing the availability of such programs as a systemic means of improving school discipline. Not infrequently, the alternative schools and programs are of such recent origin that test data have not yet been reported. Brand new schools of this kind as well as others have, no doubt, been opened since our 1996-97 data was collected.

In addition, the precisely "eighteen hundred schools" statistic is very likely an innocuous, convenient, close-to-precise rhetorical device used by state officials in public documents and speeches.

In brief, the schools in our 1996-97 data set constitute a nearly complete population. They accurately represent Georgia schools and their circumstances (Georgia Department of Public Education, 1998).

OPERATIONALIZING CONCEPTS

The Georgia data set, fortunately, is rich in the kinds of measures needed for an effective replication. Outcome variables are numerous and well-suited to the task at hand, as are explanatory factors.

Dependent Variables: Iowa Test of Basic Skills

Dependent variables or outcome measures used for third, fifth, and eighth grades are mean school-level percentile scores for eight subtests of the widely used Iowa Test of Basic Skills. Seven of the subtests are designed to measure achievement in reading comprehension, mathematics, reading vocabulary, social studies, language arts, science, and research skills. The eighth subtest is a composite measure, intended to provide a global gauge of achievement.

Mean achievement levels on all sections of the test vary dramatically from school to school. For example, school mean scores on the composite section range from 16 to 93 for grade 3; from an unlikely but verified low of 1 all the way to 95 for grade 5; and from 8 to 89 for grade 8.

Dependent Variables: Georgia High School Graduation Test

Iowa Test of Basic Skills scores are not available beyond the eighth grade. However, eleventh graders are administered the mandatory Georgia High School Graduation Test. While mean percentile scores for this test have not been reported, percent passing on first administration is available for each school and is used by the state as a performance measure.

The Graduation test gauges achievement in English, mathematics, social studies, and science. In addition, students are given a composite score. First administration passing percentages for the five scores are used as our outcome measures for the eleventh grade.

As with the Iowa Test of Basic Skills, mean achievement levels on the Graduation test vary dramatically from school to school. The percentage of eleventh graders who received a passing composite score the first time they took each subtest varied from 11 percent to 100 percent.

Independent Variables

Indepedent variables used in the analysis are the same as used in the research we are replicating: percent of all students eligible for free and reduced cost lunch (FREEPCT), and the number of students per grade level in thousand-student units (SPANSIZE). In addition, the interaction term (INTERACT), created by multiplying FREEPCT by SPANSIZE, serves as a third and crucial independent variable in each equation.

Grade spans range from one to thirteen, the latter representing ten schools with grades K through 12. Total enrollment ranges from 5 to 2795 students. Enrollment by grade level, our SPANSIZE variable, ranges from just over 1 to 778. The mean for all schools is 174.

The percentage of students eligible for free or reduced cost lunch, which we have designated FREEPCT, ranges from 0 to 100. The mean percentage for all schools is 48.

ANALYTICAL PROCEDURES

Identification and measurement of relationships in the Georgia data will be accomplished, as in the research we are replicating, through straightforward application of multiple regression analysis.

Identifying Comparable Results

Comparability with prior research, if found, will be manifest in statistically significant and negative multiplicative interaction terms created using the school size and SES variables. If comparability is present, we will take this to mean that in Georgia, too, as school size increases, the mean performance loss associated with less-advantaged students is exacerbated.

Calculating Effect Size

After the Georgia regression analyses have been done, we will use the procedure employed by Friedkin and Necochea (1988) to calculate losses which may be associated with increasing school size. Specifically, partial derivatives will be taken for each regression equation, gauging the impact of school size while holding constant percent eligible for free or reduced cost lunch.

A Regression Equation

By way of illustration, we obtained mean eighth grade reading comprehension achievement test scores for 1467 Texas secondary schools. We used these mean scores as values for the dependent variable in a multiple regression equation in which school size (measured in thousands of students per grade level) and percent eligible for free or reduced cost lunch were used as independent variables. The equation also included the muliplicative interaction term created from the two independent variables. In other words, the independent variables were those we have termed FREEPCT and SPANSIZE, along with the interaction term, INTERACT.

Regression analysis of the illustrative Texas data yielded the following equation, where Y is mean reading comprehension score, X is SPANSIZE, Z is FREEPCT, and XZ is INTERACT:

$$Y = 93.768 + 12.919X - 0.225Z - 0.294XZ$$

The equation tells us that, on the average, for every thousand-student-per-grade increment in SPANSIZE, mean school reading comprehension score increases by 12.919 points. Simultaneously, for every one percentage point increase in FREEPCT, mean reading comprehension score decreases by 0.225 points. Finally, for every one unit increment in INTERACT, mean school reading comprehension score decreases by 0.294 points.

Illustrating the Partial Derivative

Furthermore, taking the partial derivative tells us that the rate of change in Y with respect to X, holding Z constant is equal to:

$$\text{Partial Derivative} = 12.919 - 0.294Z$$

Using this result, if we set Z, our FREEPCT variable at values ranging from 0 to 100 using increments of 20, and including the FREEPCT median value of 45.9 in the middle of the distribution, we get the following:

EFFECT SIZE	FREEPCT
12.919	0.0
7.039	20.0
1.159	40.0
-1.282	44.9
-4.721	60.0
-10.601	80.0
-16.481	100.0

This means that among schools in Texas, the initial benefits associated with school size for eighth grade reading compehension achievement are diminished and quickly become increasing costs as the percentage of students eligible for free and reduced cost lunches increases.

At first, as we can see, for every one unit increment in SPANSIZE, mean reading comprehension score increases 12.919 points. However, by the time FREEPCT has reached its median, the initial benefit has become a small cost, a loss of 1.282 points for every one unit increment in SPANSIZE. When all students are eligible for free or reduced cost lunch, this cost has increased to 16.481 points per unit increment in size.

GEORGIA APPLICATIONS

This kind of analysis, estimating regression equations as in the Texas example, and then taking partial derivatives, is precisely what we will do with the Georgia data. Again, we are trying to determine if statistically significant and negative interaction terms appear, as they did in the research we are replicating, and as they did in the Texas example.

If such interactions are present, we have found another state in which interaction between size and percent less-advantaged diminishes mean achievement measured at the school level. As the Texas example makes clear, use of partial derivatives enables us to translate main effects and interaction effects into test score gains and losses.

However, if interactions are not present, our Georgia results are not consistent with findings from California and West Virginia. The plausibility of claims to generalizability are diminished.

RESULTS

Tables 1 through 29 consititute our Georgia replication. In twenty-seven of the twenty-nine analyses, we find statistically significant and negative interaction effects: as school size increases, the achievement costs for schools with less-advantaged students increase. The two exceptions are found for science in the third and fifth grades. (See Table 6 and Table 14.)

TWO EXCEPTIONS IN TWENTY-NINE ANALYSIS

In each of these exceptions, the regression coefficient corresponding to SPANSIZE was also statistically nonsignificant. Only FREEPCT yielded a statistically significant finding. As a result, partial derivatives were not taken and effect size not computed in Tables 6 and 14.

In addition, partial derivatives and effect size are not reported for Tables 5 and 13, social studies for the third and fifth grades, and Table 11, reading vocabulary for the fifth grade. In these three instances, while INTERACT was statistically significant and negative, SPANSIZE was not statistically significant.

TABLE 1
Regression Results and Effect Size: Schools
Reading Comprehension
Grade 3
Unstandardized and (Standardized) Coefficients

SPANSIZE	45.570** (.146)
FREEPCT	-0.271*** (-.488)
INTERACT	-0.988*** (-.229)
Constant Term	64.136***
Adjusted R-Squared	45.3%
	N=960

Partial Derivative = 45.570 - 0.988Z

Effect Size	FREEPCT
45.57	0.0
25.81	20.0
6.05	40.0
-7.98	54.2!
-13.71	60.0
-33.47	80.0
-53.23	100.0

*** <.001
** <.01
* <.05
! Median

TABLE 2
Regression Results and Effect Size: Schools
Mathematics
Grade 3
Unstandardized and (Standardized) Coefficients

SPANSIZE	57.059** (.170)
FREEPCT	-0.260*** (-.441)
INTERACT	-1.121*** (-.245)
Constant Term	70.475***
Adjusted R-Squared	41.4%
	N=959

Partial Derivative = 57.059 - 1.121Z

Effect Size	FREEPCT
57.06	0.0
34.64	20.0
12.22	40.0
-3.70	54.2!
-10.20	60.0
-32.62	80.0
-55.04	100.0

*** <.001
** <.01
* <.05
! Median

TABLE 3
Regression Results and Effect Size: Schools
Reading Vocabulary
Grade 3
Unstandardized and (Standardized) Coefficients

SPANSIZE	37.163* (.112)
FREEPCT	-0.321*** (-.552)
INTERACT	-0.912*** (-.201)
Constant Term	70.475***
Adjusted R-Squared	50.5%
	N=958

Partial Derivative = 37.163 - 0.912Z

Effect Size	FREEPCT
37.16	0.0
7.57	20.0
0.68	40.0
-12.27	54.2!
-17.56	60.0
-35.78	80.0
-54.04	100.0

*** <.001
** <.01
* <.05
! Median

TABLE 4
Regression Results and Effect Size: Schools
Language Arts
Grade 3
Unstandardized and (Standardized) Coefficients

SPANSIZE	81.437*** (.243)
FREEPCT	-0.226*** (-.384)
INTERACT	-1.194*** (-.334)
Constant Term	66.383***
Adjusted R-Squared	38.4%
	N=958

Partial Derivative = 81.437 - 1.194Z

Effect Size	FREEPCT
81.44	0.0
57.76	20.0
33.68	40.0
16.72	54.2!
9.80	60.0
-14.08	80.0
-37.96	100.0

*** <.001
** <.01
* <.05
! Median

TABLE 5
Regression Results and Effect Size: Schools
Social Studies
Grade 3
Unstandardized and (Standardized) Coefficients

SPANSIZE	2.563 (.009)
FREEPCT	-0.334*** (-.663)
INTERACT	-0.418* (-.107)
Constant Term	73.122***
Adjusted R-Squared	54.1%
	N=956

Partial Derivative = Not Calculated.

Effect Size	FREEPCT

SPANSIZE not statistically significant.

*** <.001
** <.01
* <.05
! Median

TABLE 6
Regression Results and Effect Size: Schools
Science
Grade 3
Unstandardized and (Standardized) Coefficients

SPANSIZE	11.359 (.036)
FREEPCT	-0.381*** (-.681)
INTERACT	-0.365 (-.084)
Constant Term	76.425***
Adjusted R-Squared	55.3%
	N=956

Partial Derivative = Not Calculated.

Effect Size	FREEPCT

SPANSIZE and INTERACT not statistically significant.

*** <.001
** <.01
* <.05
! Median

TABLE 7
Regression Results and Effect Size: Schools
Research Skills
Grade 3
Unstandardized and (Standardized) Coefficients

SPANSIZE	36.315* (.119)
FREEPCT	-0.314*** (-.588)
INTERACT	-0.822*** (-.198)
Constant Term	64.136***
Adjusted R-Squared	55.7%
	N=958

Partial Derivative = 36.314 - 0.822Z

Effect Size	FREEPCT
36.31	0.0
19.87	20.0
3.43	40.0
-8.24	54.2!
-13.01	60.0
-29.45	80.0
-45.89	100.0

*** <.001
** <.01
* <.05
! Median

TABLE 8
Regression Results and Effect Size: Schools
Composite Score
Grade 3
Unstandardized and (Standardized) Coefficients

SPANSIZE	33.356* (.103)
FREEPCT	-0.342*** (-.603)
INTERACT	-0.761** (-.173)
Constant Term	72.327***
Adjusted R-Squared	54.8%
	N=956

Partial Derivative = 33.356 - 0.761Z

Effect Size	FREEPCT
33.36	0.0
18.14	20.0
2.92	40.0
-7.89	54.2!
-12.30	60.0
-27.52	80.0
-47.74	100.0

*** <.001
** <.01
* <.05
! Median

TABLE 9
Regression Results and Effect Size: Schools
Reading Comprehension
Grade 5
Unstandardized and (Standardized) Coefficients

SPANSIZE	23.492* (.099)
FREEPCT	-0.245*** (-.571)
INTERACT	-0.723*** (-.219)
Constant Term	64.834***
Adjusted R-Squared	54.3%
	N=960

Partial Derivative = 23.492 - 0.723Z

Effect Size	FREEPCT
23.40	0.0
9.03	20.0
-5.43	40.0
-15.55	54.0!
-19.89	60.0
-34.35	80.0
-48.81	100.0

*** <.001
** <.01
* <.05
! Median

TABLE 10
Regression Results and Effect Size: Schools
Mathematics
Grade 5
Unstandardized and (Standardized) Coefficients

SPANSIZE	50.262** (.168)
FREEPCT	-0.261*** (-.484)
INTERACT	-1.180*** (-.285)
Constant Term	64.136***
Adjusted R-Squared	50.5%
	N=960

Partial Derivative = 50.262 - 1.180Z

Effect Size	FREEPCT
50.26	0.0
26.66	20.0
3.06	40.0
-13.46	54.0!
-20.54	60.0
-44.14	80.0
-67.74	100.0

*** <.001
** <.01
* <.05
! Median

TABLE 11
Regression Results and Effect Size: Schools
Reading Vocabulary
Grade 5
Unstandardized and (Standardized) Coefficients

SPANSIZE	26.840 (.080)
FREEPCT	-0.315*** (-.520)
INTERACT	-0.964** (-.207)
Constant Term	64.407***
Adjusted R-Squared	45.6%
	N=959

Partial Derivative = Not Calculated.

Effect Size	FREEPCT

SPANSIZE not statistically significant.

*** <.001
** <.01
* <.05
! Median

TABLE 12
Regression Results and Effect Size: Schools
Language Arts
Grade 5
Unstandardized and (Standardized) Coefficients

SPANSIZE	61.168*** (.207)
FREEPCT	-0.219*** (-.413)
INTERACT	-1.181*** (-.289)
Constant Term	67.389***
Adjusted R-Squared	42.4%
	N=960

Partial Derivative = 61.168 - 1.181Z

Effect Size	FREEPCT
61.17	0.0
37.55	20.0
13.93	40.0
-2.61	54.0!
-9.69	60.0
-33.31	80.0
-56.93	100.0

*** <.001
** <.01
* <.05
! Median

TABLE 13
Regression Results and Effect Size: Schools
Social Studies
Grade 5
Unstandardized and (Standardized) Coefficients

SPANSIZE	12.200 (.041)
FREEPCT	-0.341*** (-.631)
INTERACT	-0.539* (-.130)
Constant Term	71.859***
Adjusted R-Squared	52.4%
	N=960

Partial Derivative = Not Calculated.

Effect Size	FREEPCT

SPANSIZE not statistically significant.

*** <.001
** <.01
* <.05
! Median

TABLE 14
Regression Results and Effect Size: Schools
Science
Grade 5
Unstandardized and (Standardized) Coefficients

SPANSIZE	-4.062 (-.013)
FREEPCT	-0.404*** (-.718)
INTERACT	-0.228 (-.053)
Constant Term	79.256***
Adjusted R-Squared	56.0%
	N=960

Partial Derivative = Not Calculated.

Effect Size	FREEPCT

SPANSIZE and INTERACT not statistically significant.

*** <.001
** <.01
* <.05
! Median

TABLE 15
Regression Results and Effect Size: Schools
Research Skills
Grade 5
Unstandardized and (Standardized) Coefficients

SPANSIZE	26.906* (.100)
FREEPCT	-0.290*** (-.597)
INTERACT	-0.694** (-.186)
Constant Term	71.493***
Adjusted R-Squared	54.8%
	N=958

Partial Derivative = 26.906 - 0.694Z

Effect Size	FREEPCT
26.91	0.0
13.03	20.0
-0.85	40.0
-10.57	54.0!
-14.73	60.0
-28.61	80.0
-42.49	100.0

*** <.001
** <.01
* <.05
! Median

TABLE 16
Regression Results and Effect Size: Schools
Composite Score
Grade 5
Unstandardized and (Standardized) Coefficients

SPANSIZE	33.986* (.112)
FREEPCT	-0.322*** (-.590)
INTERACT	-0.896*** (-.214)
Constant Term	71.330***
Adjusted R-Squared	57.1%
	N=958

Partial Derivative = 33.986 - 0.896Z

Effect Size	FREEPCT
33.99	0.0
16.07	20.0
-1.94	40.0
-14.40	54.0!
-19.77	60.0
-37.69	80.0
-55.61	100.0

*** <.001
** <.01
* <.05
! Median

TABLE 17
Regression Results and Effect Size: Schools
Reading Comprehension
Grade 8
Unstandardized and (Standardized) Coefficients

SPANSIZE	20.969*** (.201)
FREEPCT	-0.309*** (-.549)
INTERACT	-0.560*** (-.317)
Constant Term	61.689***
Adjusted R-Squared	66.7%
	N=371

Partial Derivative = 20.969 - 0.560Z

Effect Size	FREEPCT
20.97	0.0
9.77	20.0
-1.43	40.0
-3.95	44.5!
-12.63	60.0
-23.83	80.0
-35.03	100.0

*** <.001
** <.01
* <.05
! Median

TABLE 18
Regression Results and Effect Size: Schools
Mathematics
Grade 8
Unstandardized and (Standardized) Coefficients

SPANSIZE	19.491** (.194)
FREEPCT	-0.254*** (-.468)
INTERACT	-0.542*** (-.318)
Constant Term	64.601***
Adjusted R-Squared	54.1%
	N=368

Partial Derivative = 19.491 - 0.542Z

Effect Size	FREEPCT
19.49	0.0
8.65	20.0
-2.19	40.0
-4.63	44.5!
-13.03	60.0
-23.87	80.0
-34.71	100.0

*** <.001
** <.01
* <.05
! Median

TABLE 19
Regression Results and Effect Size: Schools
Reading Vocabulary
Grade 8
Unstandardized and (Standardized) Coefficients

SPANSIZE	20.433** (.168)
FREEPCT	-0.337*** (-.513)
INTERACT	-0.638*** (-.310)
Constant Term	60.724***
Adjusted R-Squared	59.0%
	N=368

Partial Derivative = 20.433 - 0.638Z

Effect Size	FREEPCT
20.43	0.0
12.76	20.0
-5.09	40.0
-7.96	44.5!
-17.85	60.0
-30.61	80.0
-43.37	100.0

*** <.001
** <.01
* <.05
! Median

TABLE 20
Regression Results and Effect Size: Schools
Language Arts
Grade 8
Unstandardized and (Standardized) Coefficients

SPANSIZE	26.761*** (.261)
FREEPCT	-0.219*** (-.395)
INTERACT	-0.614*** (-.354)
Constant Term	63.914***
Adjusted R-Squared	50.1%
	N=367

Partial Derivative = 26.761 - 0.614Z

Effect Size	FREEPCT
26.76	0.0
14.48	20.0
2.20	40.0
-0.56	44.5!
-11.64	60.0
-22.34	80.0
-34.64	100.0

*** <.001
** <.01
* <.05
! Median

TABLE 21
Regression Results and Effect Size: Schools
Social Studies
Grade 8
Unstandardized and (Standardized) Coefficients

SPANSIZE	19.117*** (.197)
FREEPCT	-0.316*** (-.601)
INTERACT	-0.403*** (-.245)
Constant Term	65.058***
Adjusted R-Squared	67.1%
	N=367

Partial Derivative = 19.177 - 0.403Z

Effect Size	FREEPCT
19.18	0.0
11.12	20.0
3.06	40.0
1.24	44.5!
-5.00	60.0
-13.06	80.0
-21.12	100.0

*** <.001
** <.01
* <.05
! Median

TABLE 22
Regression Results and Effect Size: Schools
Science
Grade 8
Unstandardized and (Standardized) Coefficients

SPANSIZE	16.323* (.146)
FREEPCT	-0.355*** (-.586)
INTERACT	-0.502*** (-.265)
Constant Term	68.400***
Adjusted R-Squared	64.6%
	N=367

Partial Derivative = 16.323 - 0.502Z

Effect Size	FREEPCT
16.32	0.0
6.28	20.0
-3.76	40.0
-6.02	44.5!
-13.80	60.0
-23.84	80.0
-33.88	100.0

*** <.001
** <.01
* <.05
! Median

TABLE 23
Regression Results and Effect Size: Schools
Research Skills
Grade 8
Unstandardized and (Standardized) Coefficients

SPANSIZE	23.391*** (.290)
FREEPCT	-0.252*** (-.458)
INTERACT	-0.581*** (-.338)
Constant Term	63.156***
Adjusted R-Squared	59.1%
	N=367

Partial Derivative = 29.391 - 0.581Z

Effect Size	FREEPCT
29.39	0.0
17.77	20.0
6.15	40.0
3.54	44.5!
-5.47	60.0
-17.09	80.0
-28.71	100.0

*** <.001
** <.01
* <.05
! Median

TABLE 24
Regression Results and Effect Size: Schools
Composite Score
Grade 8
Unstandardized and (Standardized) Coefficients

SPANSIZE	24.330** (.220)
FREEPCT	-0.318*** (-.531)
INTERACT	-0.557*** (-.298)
Constant Term	65.433***
Adjusted R-Squared	62.8%
	N=367

Partial Derivative = 24.330 - 0.557Z

Effect Size	FREEPCT
24.33	0.0
13.31	20.0
2.05	40.0
-0.46	44.5!
-9.09	60.0
-20.23	80.0
-31.37	100.0

*** <.001
** <.01
* <.05
! Median

TABLE 25
Regression Results and Effect Size: Schools
English: Percent Passing First Time
Grade 11
Unstandardized and (Standardized) Coefficients

SPANSIZE	8.008*** (.215)
FREEPCT	-0.095*** (-.394)
INTERACT	-0.159*** (-.180)
Constant Term	95.038***
Adjusted R-Squared	35.6%
	N=304

Partial Derivative = 8.008 - 0.159Z

Effect Size	FREEPCT
8.01	0.0
4.83	20.0
1.65	40.0
1.43	41.4!
-1.53	60.0
-4.63	80.0
-7.89	100.0

*** <.001
** <.01
* <.05
! Median

TABLE 26
Regression Results and Effect Size: Schools
Mathematics: Percent Passing First Time
Grade 11
Unstandardized and (Standardized) Coefficients

SPANSIZE	14.861*** (.205)
FREEPCT	-0.198*** (-.418)
INTERACT	-0.520*** (-.303)
Constant Term	91.798***
Adjusted R-Squared	49.0%
	N=303

Partial Derivative = 14.861 - 0.520Z

Effect Size	FREEPCT
14.86	0.0
4.46	20.0
-5.94	40.0
-6.67	41.4!
-16.34	60.0
-26.74	80.0
-37.14	100.0

*** <.001
** <.01
* <.05
! Median

TABLE 27
Regression Results and Effect Size: Schools
Social Studies: Percent Passing First Time
Grade 11
Unstandardized and (Standardized) Coefficients

SPANSIZE	28.284*** (.301)
FREEPCT	-0.238*** (-.389)
INTERACT	-0.659*** (-.297)
Constant Term	80.386***
Adjusted R-Squared	50.6%
	N=303

Partial Derivative = 28.284 - 0.659Z

Effect Size	FREEPCT
28.28	0.0
15.10	20.0
1.92	40.0
1.00	41.4!
-11.26	60.0
-24.44	80.0
-37.62	100.0

*** <.001
** <.01
* <.05
! Median

TABLE 28
Regression Results and Effect Size: Schools
Science: Percent Passing First Time
Grade 11
Unstandardized and (Standardized) Coefficients

SPANSIZE	28.600*** (.256)
FREEPCT	-0.315*** (-.433)
INTERACT	-0.792*** (-.299)
Constant Term	79.637***
Adjusted R-Squared	53.8%
	N=303

Partial Derivative = 28.600 - 0.792Z

Effect Size	FREEPCT
28.60	0.0
14.02	20.0
-3.08	40.0
-4.19	41.4!
-18.92	60.0
-29.72	80.0
-50.60	100.0

*** <.001
** <.01
* <.05
! Median

TABLE 29
Regression Results and Effect Size: Schools
Composite Score: Percent Passing First Time
Grade 11
Unstandardized and (Standardized) Coefficients

SPANSIZE	35.928*** (.300)
FREEPCT	-0.330*** (-.424)
INTERACT	-0.922*** (-.326)
Constant Term	72.111***
Adjusted R-Squared	58.2%
	N=303

Partial Derivative = 35.928 - 0.922Z

Effect Size	FREEPCT
35.93	0.0
17.45	20.0
-0.95	40.0
-2.24	41.4!
-19.39	60.0
-37.83	80.0
-56.27	100.0

*** <.001
** <.01
* <.05
! Median

ALL TOLLED

Twenty-nine tables may seem excessive, and certainly there are well known, easy to execute ways to summarize these findings, sharply reducing the number of separate analyses. A good case can be made, however, that by including all the analyses, in table after table, we make unmistakably clear that the Georgia data enabled us to produce a replication which is unambiguously consistent with earlier findings regarding size-by-SES interaction effects. In Georgia schools, too, as school size increases, the achievement costs associated with less-advantaged students increases.

WHAT ABOUT SCHOOL DISTRICTS?

Some of the same literature which alerted us to the existence of size-by-SES interactions at the school level also raised the possibility of similar size-related achievement costs at the district level. We have summarized the Georigia district results in Tables 30 through 33.

The only dependent variables used are the district composite scores, global measures of achievement, for grades 3, 5, 8, and 11. Neither SPANSIZE nor INTERACT is

TABLE 30
Regression Results and Effect Size: Districts
Composite Score
Grade 3
Unstandardized and (Standardized) Coefficients

SPANSIZE	0.799 (.079)
FREEPCT	-0.379*** (-.606)
INTERACT	-0.009 (-.040)
Constant Term	70.579***
Adjusted R-Squared	38.3%
	N=176

Partial Derivative = Not Calculated.

Effect Size	FREEPCT

SPANSIZE and INTERACT not statistically significant.

*** <.001
** <.01
* <.05
! Median

TABLE 31
Regression Results and Effect Size: Districts
Composite Score
Grade 5
Unstandardized and (Standardized) Coefficients

SPANSIZE	0.412 (.042)
FREEPCT	-0.426*** (-.707)
INTERACT	0.005 (.019)
Constant Term	71.507***
Adjusted R-Squared	51.0%
	N=175

Partial Derivative = Not Calculated.

Effect Size	FREEPCT

SPANSIZE and INTERACT not statistically significant.

*** <.001
** <.01
* <.05
! Median

TABLE 32
Regression Results and Effect Size: Districts
Composite Score
Grade 8
Unstandardized and (Standardized) Coefficients

SPANSIZE	0.959 (.105)
FREEPCT	-0.407*** (-.674)
INTERACT	-0.029 (-.138)
Constant Term	70.452***
Adjusted R-Squared	48.9%
	N=171

Partial Derivative = Not Calculated.

Effect Size	FREEPCT

SPANSIZE and INTERACT not statistically significant.

*** <.001
** <.01
* <.05
! Median

TABLE 33
Regression Results and Effect Size: Districts
Composite Score
Grade 11
Unstandardized and (Standardized) Coefficients

SPANSIZE	0.507 (.041)
FREEPCT	-0.581*** (-.723)
INTERACT	-0.004 (-.013)
Constant Term	76.425***
Adjusted R-Squared	52.9%
	N=171

Partial Derivative = Not Calculated.

Effect Size	FREEPCT

SPANSIZE and INTERACT not statistically significant.

*** <.001
** <.01
* <.05
! Median

statistically significant in any of the four district-level analyses. The size-by-SES interaction effect which was so conspicuous at the school level is not present at the district level.

These findings are consistent with analyses not reported here which used all twenty-nine outcome measures. Only four, research skills in the 3rd and 5th grades, language arts in the 5th grade, and math in the 8th grade resulted in statistically significant and negative coefficients for the INTERACT variable.

CAUTIONARY COMMENTS

At this point it is fitting to mention some limitations of our analytical procedures. Most important is the fact that results of application of multiple regression analysis may be misleading if requirements intrinsic to a set of well known assumptions are not met.

Multicollinearity

An important concern whenever interaction terms are used in multiple regression analysis is correlation among independent variables. Such correlations, often referred to as confouding, are almost always present.

As correlations among independent variables increase, however, estimates of regression coefficients become less precise. This is due to inflation of standard errors of estimates of regression coefficients. In the most extreme case, when an independent variable is a perfect linear function of one or more others, the standard errors of the estimates becomes infinitely large, and coefficients cannot be estimated.

Correlations among independent variables are rarely perfect, however, raising the question "How large is too large?" A variety of statistical tools has been developed to assist in answering this question, though each has an unsettling rule-of-thumb character. Among the most commonly used is the variance inflation factor (VIF).

The oft-cited rule-of-thumb of the VIF is a numerical magnitude of 10 (Chatterjee and Price, 1991; Kennedy, 1992; Gujurati, 1995). In other words, if no independent variable in a multiple regression equation corresponds to a VIF of 10 or larger, multicollinearity will not result in imprecise estimates. The VIF's in our analyses range from 1.10 to 8.80.

Multicollinearity and Interaction Terms

As noted, we are particularly interested in this assumption and its violation because interaction terms, as we have seen, are usually created by mulitiplying together two or more independent variables. As a result, strong correlations among the original independent variables and the interaction terms are commonplace (Aiken and West, 1991). In our analyses, this means that FREEPCT and SPANSIZE may be closely correlated with INTERACT.

Centered Score Regression

One response to multicollinearity caused by creation of interaction terms is centering. Instead of using the actual values of the original independent variables, deviations around means are computed (Kromrey and Foster-Johnson, 1998). These centered variables are then used in constructing the interaction term and in doing the regression analysis. Resulting VIF's will be approximately equal to 1.0.

We have already noted, however, that the largest of our VIF values was 8.80. (Most were much smaller). Multicollinearity was not so serious in our analyses as to require centering, according to conventional criteria.

Multicollinearity with a Small Number of Cases

In spite of the foregoing, Fox (1997) has suggested that VIF's typically underestimate loss of precision due to multicollinearity. Moreover, when statistical power is diminished due to both multicollinearity and a comparatively small number of cases, remedies such as centered score regression may be advisable, even with acceptable VIF values.

For this reason, we replicated our original analyses of district data after centering all variables. Furthermore, since the district-level SPANSIZE variable has an unusually sharp skew to the right, we took natural logarithms of this variable, making its distribution approximately normal.

The outcomes of these analyses, not reported in tabular form here, were little different from the regression runs made without centering and logging. There was an increased number of close calls for the INTERACT variable, but nothing which changes our conclusions for the district level.

Regression Model Specification

Proper specification of multiple regression equation is determined by meeting two criteria: independent variables have not been erroneously included or excluded, and the proper functional form has been employed. In practice, the second criterion typically means not assuming linear relationships when relationships are, in fact, nonlinear. Examination of scatterplots, not included here, illustrating patterns of association between our independent variables and dependent variables makes clear that troublesome departures from linearity are not present.

The first criterion, inclusion of the proper independent variables is, in this instance, a more obvious concern. After all, everyone agrees that explanation of school-level mean achievement inevitably includes more than size, socioeconomic status, and a multiplicative interaction term.

Regression Model Sensitivity

It remains the case, however, that proper specification of regression models in research on educational achievement is substantively uncertain and theoretically very thin. Beyond that, it is not our intention to produce a defensible production function or input-output model. Instead, the issue of regression model specification arises in response to the following: will our report regarding statistically significant and negative muliplicative interaction terms still prove robust with alternative specifications?

In analyses not reported here, we have included two additional independent variables in each equation: percent of students who are black, and percent of students belonging to other racial or ethnic minority groups. Inclusion of these two additional explanatory factors had little effect on our regression results. One consistent outcome, however, was a modest increase in the numerical magnitude of the interaction term in the school-level equations.

Ecological Inference

All our analyses deal with aggregated data. Such analyses are not necessarily sound bases for inferences to individuals. Erroneous efforts to make such inferences place us in danger of falling victim to what is commonly termed the ecological fallacy.

Avoiding the ecological fallacy, avoiding erroneous statements about individual behavior based on aggregated data, can be accomplished with regression analysis, provided we meet three criteria: grouping is not done on the dependent variable itself; grouping is not done on an independent variable erroneously excluded due to model misspecification; and grouping is not done on variables statistically unrelated to the independent variables and the error term (Langbein and Lichtman, 1978; King, 1997).

As best we can determine, even with suspect model specification, we have met these standards. However, even if inferences from our aggregated data to individuals are not made, the pernicious connection between size and socioeconomic status is abundantly evident for Georgia schools.

CONCLUSION

At the outset, we made clear that school size remains a variable which merits continued investigation as an educational resource, a determinant of educational achievement. We also made the case that size is pertinent to discussions of educational equity, as well as effectiveness.

We were less certain, however, as to whether or not school-level size-by-SES interactions effects, which raise both effectiveness and equity issues, would prove robust. Having replicated the research which first generated interest in these effects using a large Georgia data set, we have found the effects to be robust, indeed.

The Georgia results are especially interesting because of their grade-to-grade, test-to-test consistency. The generalizability of the claim that the achievement costs for less-advantaged students are exacerbated by increasing school size has gained credibility.

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APPENDIX

Bivariate correlations, computed above and below the median for school size, of FREEPCT with achievement measures for grades 3, 5, 8, and 11. Notice that in every instance, the correlation for larger schools, those above the median, has a larger absolute value.

Grade 3

	Read. Comp.	Math.	Read. Voc.	Lang. Arts	Socl. Stud.	Sci.	Rsrch. Skls.	Comp.
Above	-.78	-.74	-.80	-.70	-.82	-.83	-.83	-.82
Below	-.56	-.53	-.60	-.47	-.64	-.65	-.63	-.63

Grade 5

	Read. Comp.	Math.	Read. Voc.	Lang. Arts	Socl. Stud.	Sci.	Rsrch. Skls.	Comp.
Above	-.82	-.80	-.79	-.75	-.80	-.81	-.82	-.84
Below	-.64	-.59	-.54	-.51	-.64	-.69	-.65	-.66

Grade 8

	Read. Comp.	Math.	Read. Voc.	Lang. Arts	Socl. Stud.	Sci.	Rsrch. Skls.	Comp.
Above	-.89	-.82	-.81	-.82	-.88	-.88	-.87	-.86
Below	-.72	-.63	-.70	-.56	-.73	-.72	-.64	-.70

Grade 11

	Eng.	Math.	Socl. Stud.	Sci.	Comp.
Above	-.77	-.81	-.82	-.85	-.86
Below	-.43	-.58	-.56	-.60	-.62

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